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DECEMBER 1958

DRAG AND STABILITY PROPERTIES OF THE 105MM SHELL, HE, T388 (U)

EUGENE D. BOYER

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Eugene D. Boyer

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EDBoyer/sec
Aberdeen Proving Ground, Md.
December 1958

DRAG AND STABILITY PROPERTIES OF THE 105-MM SHELL, HE, T388 (U)

(UNCLASSIFIED) ABSTRACT

The drag and stability properties of the 105-mm, HE, T388 shell are presented. These data were obtained from Transonic Range firings.

(UNCLASSIFIED) TABLE OF SYMBOLS

A	Axial moment of inertia (lb - in^2)
B	Transverse moment of inertia (lb - in^2)
d	Diameter (in)
m	Mass (lb)
K_D	Drag coefficient
K_M	Overturning moment coefficient
K_L	Lift force coefficient
$K_H - K_{MA}$	Damping moment coefficient
K_T	Magnus moment coefficient
$\overline{\delta^2}$	Mean squared yaw (deg^2)
$K_{D_{\delta^2}}$	Yaw drag coefficient (rad^{-2})
$\lambda_{1,2}$	Yaw damping rates (ft x 10^3)$^{-1}$
s	Gyroscopic stability factor
$\bar{s}$	Dynamic stability factor
N	Number of yaw stations
N_T	Number of timing stations
ϵ_y	Error in yaw fit (rad)
ϵ_s	Error in swerve fit (ft)
$K_{1,2}$	Sizes of yaw arms at mid range
$\phi'_{1,2}$	Turning rates of yaw arms (deg/ft)

(~~CONFIDENTIAL~~) INTRODUCTION

At the request of the Canadian Armament Research and Development Establishment (CARDE), BRL fired, through the Transonic Range[1], four versions of the 105-mm, HE, T388 shell, designed at CARDE (Figure 1). The four types varied only in body length and were designed to bracket a stability factor of 1.8 at M = 1.1. These firings were suggested by the Bi-partite Standardization Committee as a part of the development of improved 105-mm howitzer ammunition. The firings were to determine the drag properties of these shell from M = 0.6 to M = 1.5 and the gyroscopic stability factors at M = 1.1.

Early tests indicated that the drag of these shell was approximately 20% lower than that of the standard M1 shell[2,3]. The T388 shell has a long hollow boattail and it was thought that the drag could be further reduced by bleeding air into the base from the body of the shell. Three shell of each type were available for stability firings at M = 1.1, and an additional ten shell of Type 1 for base-bleed experiments.

The shell were launched from a 105-mm howitzer (1 - 20 twist). A yaw inducer was employed on the six rounds at M = 1.1. This was done in order to obtain adequate yaw levels for a yaw reduction. The physical properties of the shell are given in Figure 1.

(~~CONFIDENTIAL~~) STABILITY

The stability factors and other aerodynamic properties of the shell are given in Table I. The reduction parameters are given in Table II. The stability factors, as determined at 465 feet from the muzzle, at about M = 1.1, vary from 1.66 for Type 1 to 1.95 for Type 2. All types are dynamically stable at the velocity tested, M = 1.1. No yaw analysis was made at other velocities fired. The yaw damping rates appear to be sensitive to yaw level but the evidence, on this small sample, is rather weak.

([redacted]IAL) DRAG COEFFICIENT

The drag force coefficient, K_D, was obtained by fitting a cubic equation to the time-distance data for each round. These data were then reduced to zero-yaw by the relationship $K_D = K_{D_o} + K_{D_{\delta^2}} \delta^2$. $K_{D_{\delta^2}}$, the yaw drag coefficient, was determined to be 2.0 (per square radian) at M = 1.1. This value was used to reduce all drag values to zero yaw (Figure 2). A shadowgraph of Type 4 at M = 1.086 is given in Figure 3. Three shell of Type 3 and one shell each of the other three types were fired at M = 1.1. When no difference was noted in the drag for the different types, the six remaining shell were fired over a range of Mach numbers to establish the drag curve. In comparing drag values of the M1 with that of the T388 (Figure 2) it is seen that in the subsonic region drags are the same for both shell while in the supersonic region the T388 drag is 20% less than that of the M1.

To test base-bleed designs Picatinny Arsenal modified ten Type 1 T388 shell by drilling bleed-holes with a 0.25 inch diameter at 29° to the axis of the shell. Five variations of vented areas varying from 6 to 48 holes, located before and/or after the rotating band, were tested (Figures 4 and 5). Details and physical properties for each type are listed in Table III. These designs showed no improvement in drag (Figure 2). In fact, for the two rounds fired in the subsonic region there appears to be an increase in drag. The 20% drag increase at $M > 1.2$, for modification 1, however, is due to the removal of the boattail and not to the presence of the vent holes.

([redacted]) CONCLUSION

The ballistic characteristics of these four types of shell differ very little. At M = 1.1 the gyroscopic and dynamic stabilities are similar and adequate. Therefore, because of the measured similarities of the ballistic characteristics of all four types the selection of the final type can not be made on the basis of these characteristics.

The hoped for further reduction in drag by bleeding air into the base was not achieved. The intakes were located upstream of the boattail where the surface pressures are higher. These locations, however, severely limit the total intake area which can be achieved without jeopardizing the strength of the projectile. Hence, only about one half of the optimum intake area could be achieved even with 48 holes. This partially accounts for the negative results, and perhaps inefficient ducting with 1/4-inch diameter holes further reduces the amount of air bled into the base cavity. It is rather doubtful that further experimentation with base-bleed with this design would be fruitful.

Eugene D. Boyer
EUGENE D. BOYER

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[redacted]

(CONFIDENTIAL) TABLE I

AERODYNAMIC DATA

Type	Round	M	K_D	$\sqrt{\overline{\delta^2}}$ (deg)	K_M	K_N	$K_H - K_{MA}$	K_T	s	$\bar{s}$
1	4989	.755	.0494	2.0						
1	4903	1.106	.1370	2.96	1.745	.72	4.71	-.17	1.66	1.15
1	4980	1.220	.1278	1.34						
2	4992	.629	.0500	1.9						
2	4902	1.083	.1406	2.81	1.673	.83	4.56	-.17	1.73	1.16
2	4978	1.364	.1272	.9						
3	4899	1.101	.1727	8.35	1.537	.93	4.00	-.20	1.95	1.44
3	4900	1.106	.1290	1.18	1.574	.80			1.84	
3	4901	1.110	.1334	2.05	1.650	.80	4.71	-.15	1.80	1.01
4	4993	.971	.0788	.8						
4	4904	1.086	.1350	2.64	1.600	.76	4.44	-.18	1.88	1.18
4	4979	1.457	.1201	1.2						

[redacted]

[redacted] TABLE II

REDUCTION PARAMETERS

Round	K_1 (rad)	K_2 (rad)	$\lambda_2 \times 10^3$ $(ft)^{-1}$	$\lambda_2 \times 10^3$ $(ft)^{-1}$	ϵ_y (rad)	ϵ_s (ft)	S_L (ft)	ϕ_1' (deg/ft)	ϕ_2' (deg/ft)
4903	.033	.039	.38	.60	.0016	.0064	.04	3.46	.78
4902	.032	.036	.39	.63	.0019	.0130	.04	3.54	.75
4899	.111	.087	.18	.75	.0020	.0065	.15	3.73	.67
4900	.015	.004			.0018			3.62	.70
4901	.021	.028	.50	.52	.0018	.0073	.04	3.65	.73
4904	.035	.029	.36	.62	.0022	.0060	.04	3.75	.71

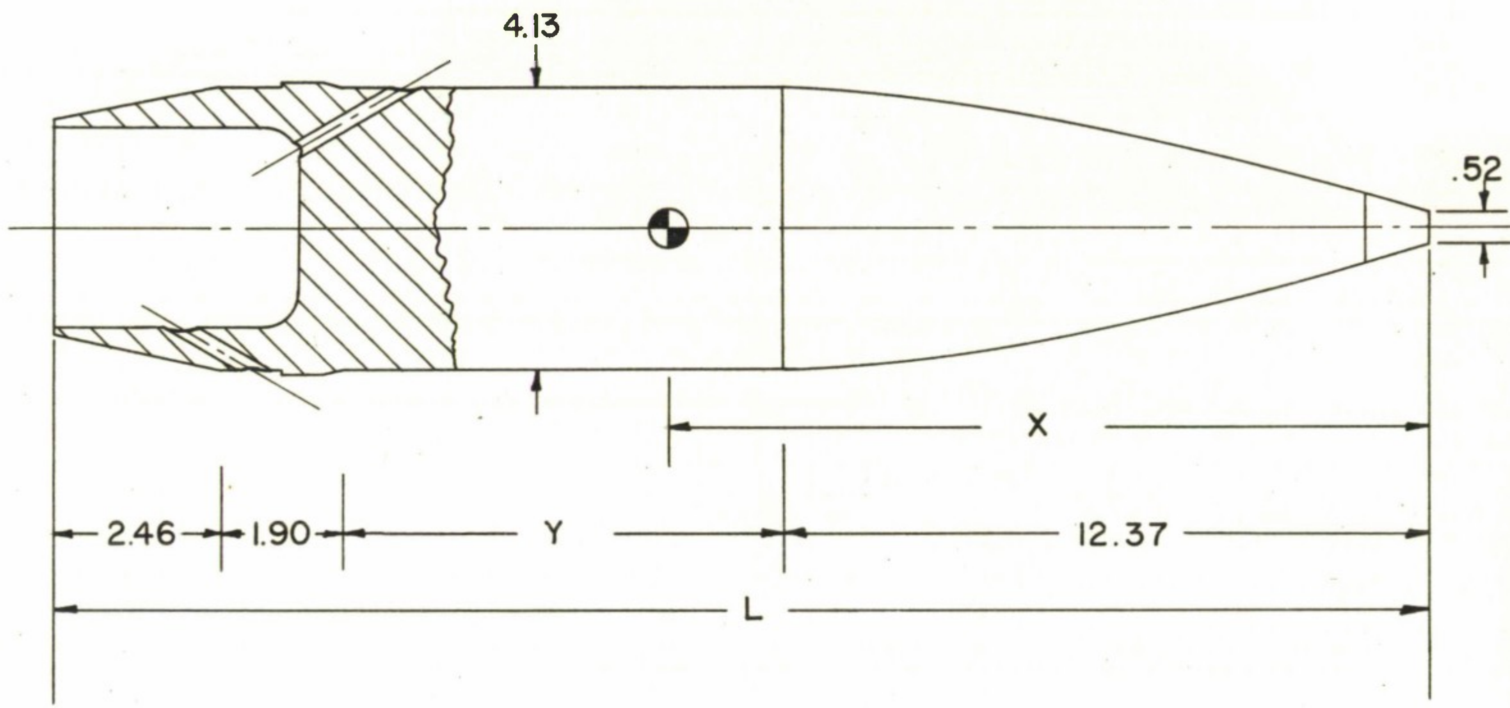
TABLE III

BASE-BLEED DESIGNS

Modifications	No. holes ahead of band	No. holes behind band	Wt. (lbs)	cm (in from nose)	Round	M	K_D	$\sqrt{\overline{\delta_2}}$
1*	24		25.95	12.92	4985	1.222	.1563	.96
					4988	1.396	.1467	.80
2	24	24	28.18	13.62	4984	1.241	.1322	1.27
					4991	.760	.0625	1.59
3	12		28.80	13.78	4983	1.263	.1295	1.20
					4990	.745	.0535	1.18
4	6		28.90	13.76	4982	1.222	.1313	2.36
					4987	1.457	.1199	1.31
5		24	28.66	13.71	4981	1.210	.1270	1.52
					4986	1.409	.1201	.89

*Boattail removed - overall length = 20.42 in.

PHYSICAL PROPERTIES



TYPE	WT (LBS)	A (LBS-IN²)	B (LBS-IN²)	X CM (IN)	L (IN)	Y
1	29.07	72.60	919.0	13.78	23.22	6.49
2	28.76	71.40	892.0	13.59	23.00	6.27
3	29.20	72.60	885.7	13.45	22.84	6.11
4	29.08	72.27	861.0	13.29	22.63	5.90

NOTE: ALL DIMENSIONS ARE IN INCHES

FIGURE 1

ZERO-YAW DRAG COEFFICIENT VS MACH NUMBER

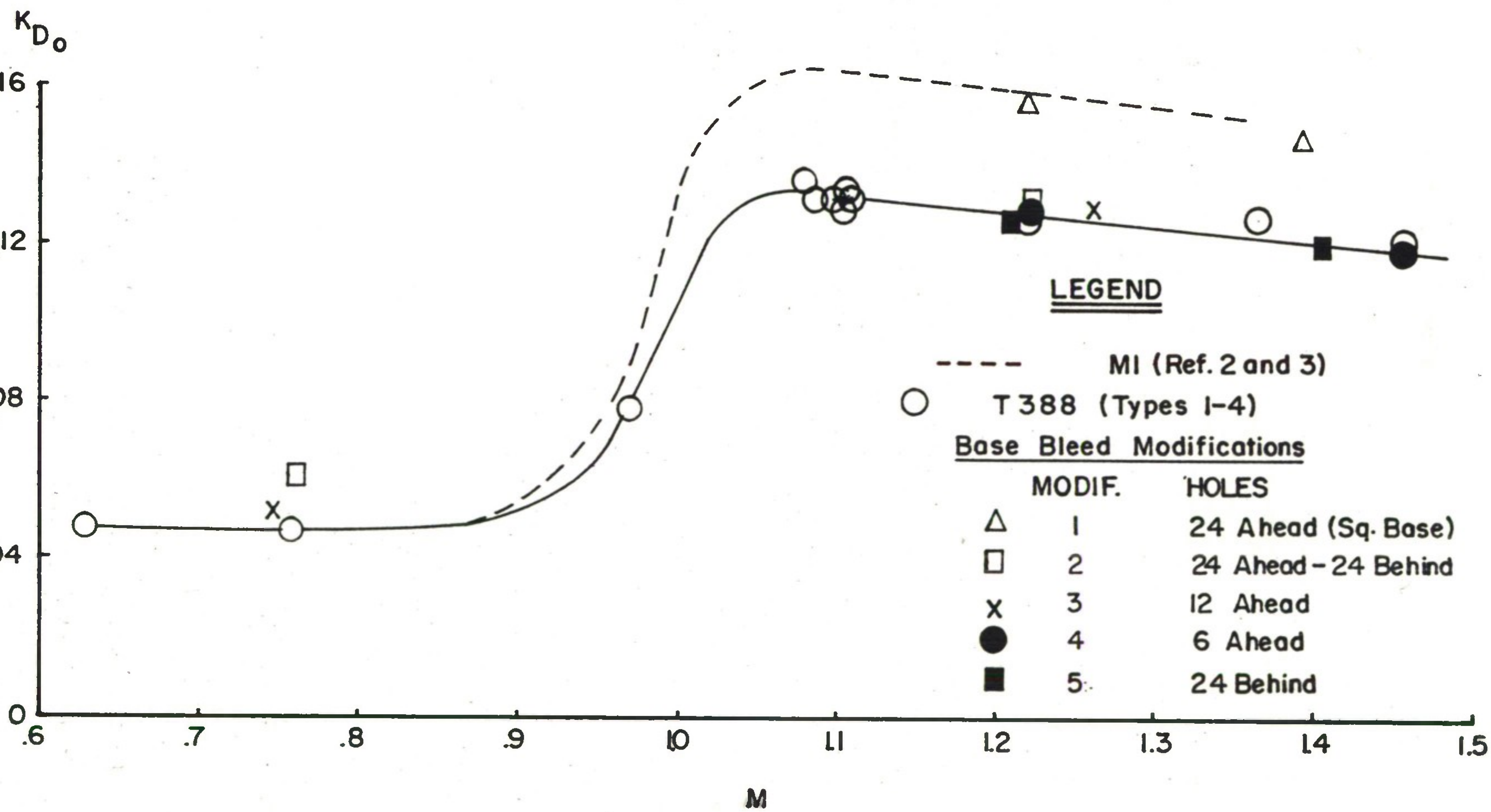


FIG. 2

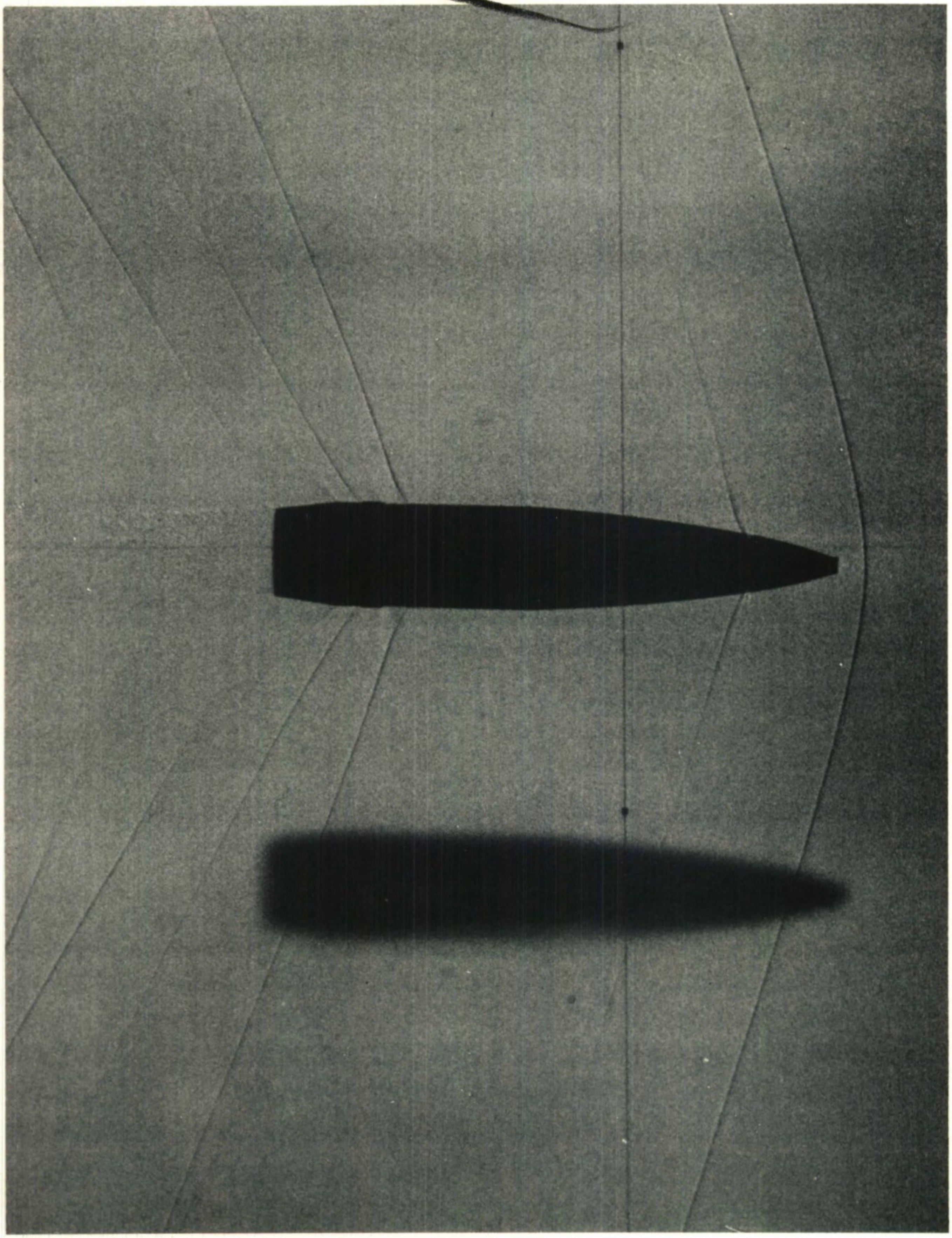


Figure 3. M = 1.086

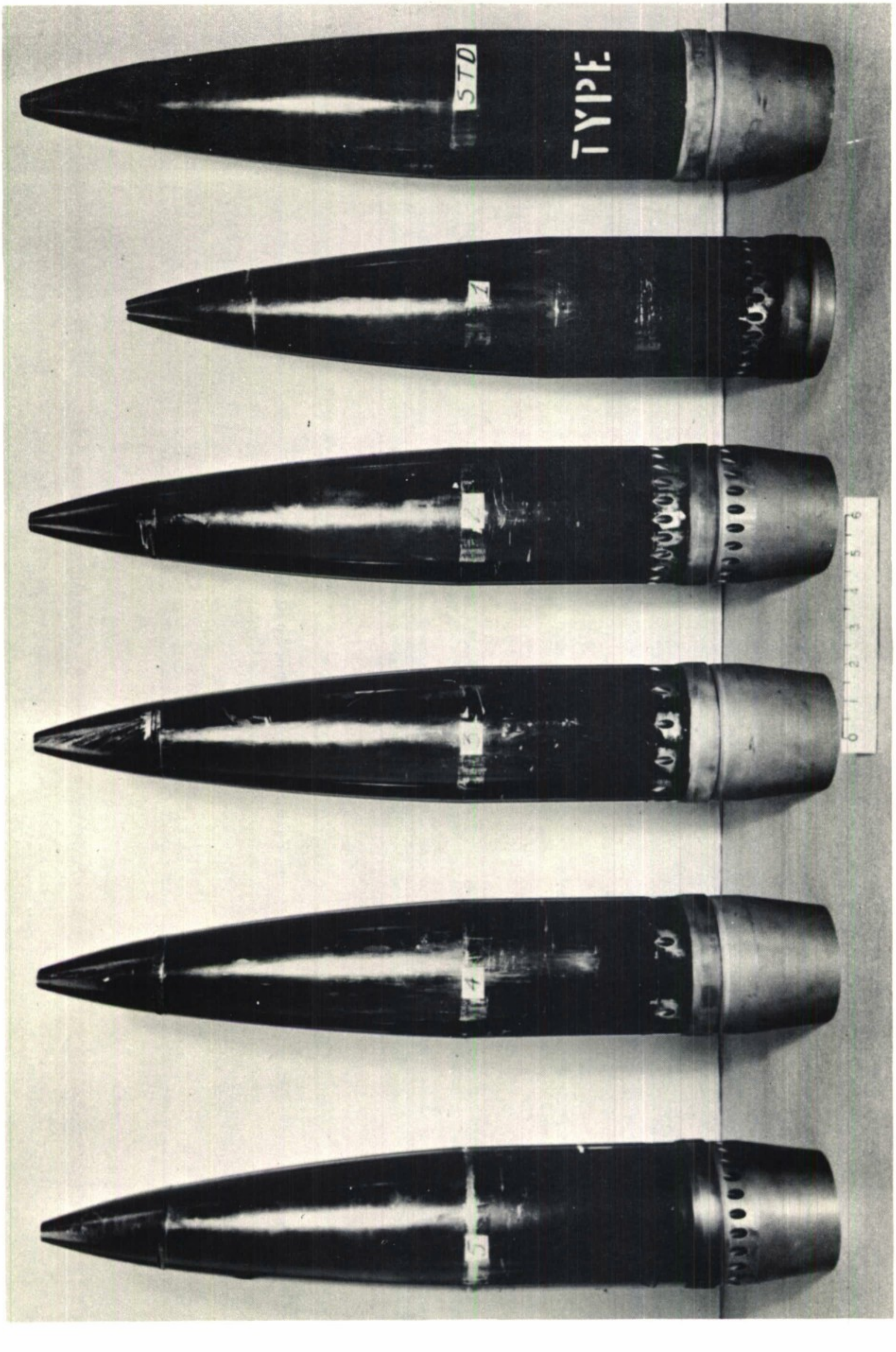


Figure 4. Base-Bleed Designs

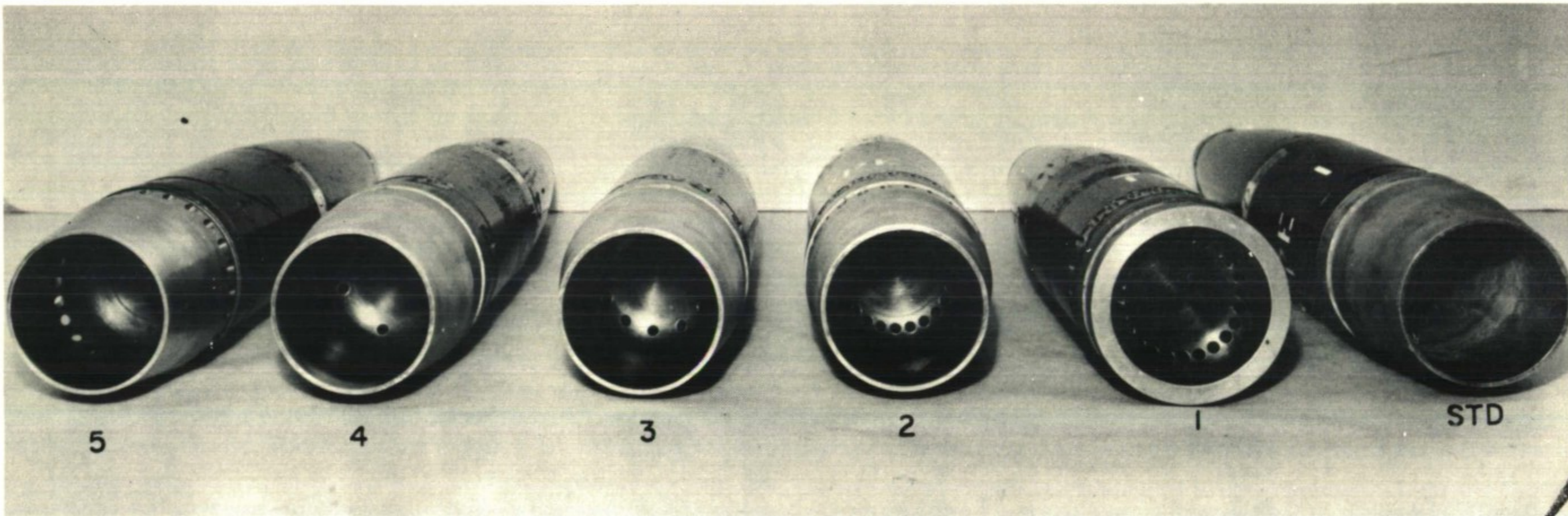


Figure 5. Base-Bleed Designs

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